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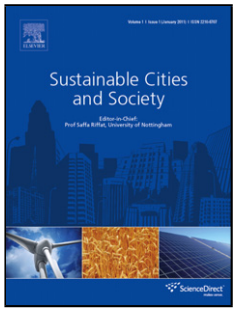

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Promoting urban regeneration and aging in place: APRAM - an interdisciplinary method to support decision-making in building renovation.

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Highlights

- New interdisciplinary method to achieve urban regeneration and population targets.
- Architectural and Psychoenvironmental Retrofitting Assessment Method (APRAM).

- Decision support system for owners or public agents in building renovation.
- Integral diagnosis of retrofitting interventions from various perspectives.
- Close connections between architectural diagnosis and residents' perceptions.

Abstract

Current European policies aim to promote the sustainable urban regeneration of housing stock while ensuring aging in place. Following these targets, this research proposes the Architectural and Psycho-environmental Retrofitting Assessment Method (APRAM) as an interdisciplinary decision support system, specifically designed to be applied in building renovation, which considers architectural demands and residents' perceptions. This method generates an integral diagnosis that combines an architectural evaluation, through technical inspection grids, and psycho-environmental perceptions, by gathering residents' responses from a participatory survey, in order to facilitate decision-making regarding renovation proposals. Retrofitting interventions, structured in public space, building, and dwelling scales, are assessed using architectural priority levels as well as social and engagement indicators of satisfaction, attachment, social need, and willingness to participate, thereby establishing a decision support system for property owners or public entities. APRAM is applied and tested in a residential neighbourhood of Lisbon (Portugal), for which its architectural, social and economic reports are defined in a summary table and a graphical display that show the integral performance of each intervention. Over 80% of responses involve major demands for which the proposed method shows close connections between the architectural diagnosis and residents' perceptions for the decision-making process.

Keywords: urban regeneration; building renovation; population aging; interdisciplinary method; decision-making; residents' perceptions.

1. Introduction

The growth and expansion of European cities in the second half of the 20th century, mainly due to the population increase and the mass exodus from the countryside to the city, generated an architectural style that would satisfy the huge demand for housing in very short implementation times. This resulted in numerous residential neighbourhoods of an exclusively functional character (European Union (UE), 2015), whose dwellings were conceived as a result of a simple division of areas in accordance with the different uses of the rooms (Causapié, Balbontín, Porras, & Mateo, 2011). During the 21st century, this process has evolved into a large number of obsolete residential neighbourhoods that consume energy inefficiently and fail to satisfy minimum conditions of security, habitability, and comfort for residents (Aksoezen, Daniel, Hassler, & Kohler, 2015; Ferrante, 2014; United Nations, 2013).

Regarding population, the aging of the progressive world population is especially significant in Europe, with 18% of people now over 65 years old; this percentage is expected to rise to 33%, which is one third of the European population, by 2050 (European Commission, 2015). This demographic process is associated with a higher environmental impact in residential built-up environments, since this elderly population sector increases energy consumption due to its tendency to spend more time at home and to suffer from a higher sensitivity to temperature and comfort conditions (Van Hoof, Schellen, Soebarto, Wong, & Kazak, 2017; World Health Organization, 2015). Therefore, besides in addition to promoting urban regeneration in the housing stock, European policies are also promoting "Aging at home" or “Aging in place” (European Commission, 2012; Mestheneos, 2011) to ensure the quality of life of elderly people in their usual residential environments.

Following these conditions, it is crucial to generate effective procedures and methods in urban regeneration to support the decision-making processes of economically feasible retrofitting interventions that involve social benefits, thereby creating age-friendly urban environments (Ruza et al., 2014; Serrano-Jiménez, Barrios-Padura, & Molina-Huelva, 2018; Sixsmith & Sixsmith, 2008). Various studies have considered urban regeneration with real perspectives from social and personal factors within this context, and have implemented retrofitting interventions with positive socio-economic impact (Santangelo & Tondelli, 2017; Tadeu et al., 2016). In addition, several other studies, such as those developed by Singh et al. (2013) and Serrano-Jiménez et al. (2017), have generated new action protocols that include social demands of residents by using participatory surveys. Recently, Monzón and López-Mesa (2018) and Riera Pérez et al. (2018) have highlighted the need to implement tools and/or methods that introduce multidisciplinary indicators of analysis to support decision-making in building renovation.

In this context, there is a need to verify the additional impact or limitations that an aging population may assume to incur on the urban regeneration process (Kovacic, Summer, & Achammer, 2015). Therefore, the desire to promote aging in place successfully is dependent not only on the physical attributes of residential environments, but also on psycho-environmental variables of their residents (Gilleard, Hyde,

& Higgs, 2007). Residential satisfaction has been considered one of the most influential aspects to achieve residential quality of life (Aragonés et al., 2017). This concept encompasses various domains, such as building, neighbourhood, and neighbours, and it remains essential to assess social needs and to design effective architectural interventions for the elderly (Koh, Leow, & Wong, 2015; Rioux & Werner, 2011). Another variable that has been described as significant in urban regeneration for an aging population is that of place attachment: the positive bond between people and physical settings that helps to cultivate a territorial identity (Brown, Perkins, & Brown, 2003).

These statements justify the establishment of decision-making protocols in urban regeneration that consider social and personal factors, and specifically examine the critical incidence that can be produced in cases where an aging population exists. Therefore, the psycho-environmental variables should be considered useful in urban regeneration processes (Fernández-Portero, Alarcón, & Barrios-Padura, 2017) as information supplementary to the set of architectural interventions diagnosed from technical and architectural procedures, thereby allowing a more exhaustive assessment, diagnosis, and decision-making method to be applied regarding residential building stock (Mcarthur & Jofeh, 2016; Olsson, Malmqvist, & Glaumann, 2016).

This research develops and tests an Architectural and Psycho-environmental Retrofitting Assessment Method (APRAM), which is an interdisciplinary method that has been specifically designed to be applied in residential retrofitting interventions and focused on the elderly, and that, considering the occupant behaviour, guides the decision-making process in building renovation. The originality of this method consists of the integration of an architectural diagnosis, developed through technical inspection grids, with a psycho-environmental assessment of the needs and preferences of the resident population, through a participatory survey. This paper starts with the definition of the methodology APRAM, and this interdisciplinary method is then applied in a reference case study involving a residential neighbourhood of Lisbon (Portugal) that complies with its application parameters. The technical grid and survey results support the decision-making in retrofitting interventions through architectural priority levels and social indicators, which are presented in a summary table and graphical diagrams that allow owners, promoters and neighbourhood communities to choose the most appropriate interventions from an effective and multidisciplinary point of view.

2. Method

This section defines the Architectural and Psycho-environmental Retrofitting Assessment Method (APRAM). The principal usefulness of this method is that it specifically focuses on building renovation and introduces multiple dimensions of analysis that allow an integral diagnosis to be achieved. This diagnosis combines an objective dimension, coming from technical results of architectural inspections, and a subjective dimension that gathers social perceptions of residents, in order to choose effective retrofitting interventions.

Figure 1 shows a general outline of the APRAM operation method through boxes and arrows that simulate the process, and in certain cases, additional or procedural information is added and marked with dashed lines. This is an open and flexible procedure, which could be applied in different case studies from various cities, and is adaptable to diverse architectural, social and economic contexts. Following the scheme, this decision-making method combines: architectural demands, such as the technical results that, considering non-compliance, deficit, or conservation levels, classify the necessary interventions into three levels of priority; and residents' perceptions, such as those social and engagement indicators related to residential satisfaction, place attachment, social needs, and willingness to participate.

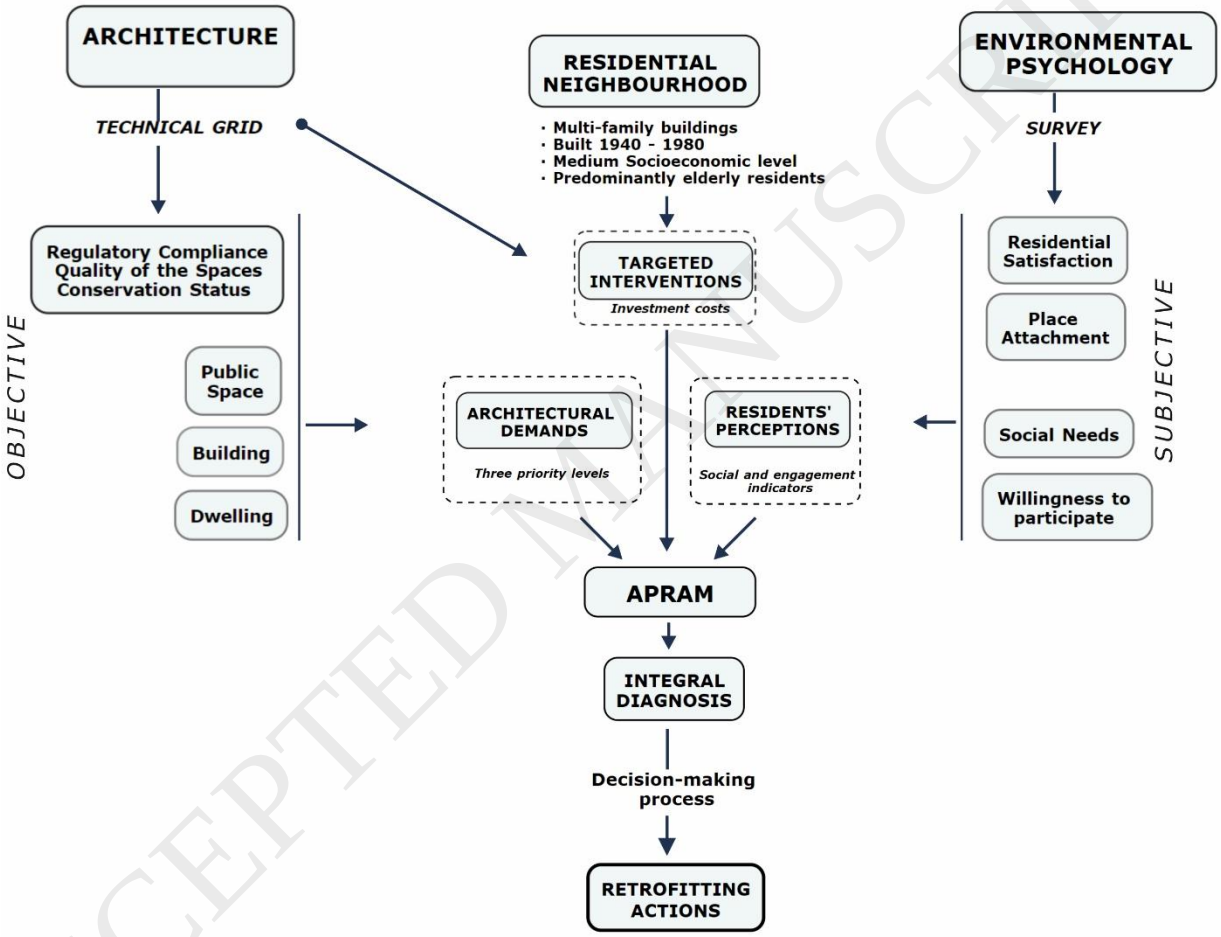

Figure 1. General scheme of the Architectural and Psycho-environmental Retrofitting Assessment Method (APRAM).

The inspection procedure distinguishes between three scales: public space, building, and dwelling. Public space is considered as the immediate outside space that exists between buildings in the neighbourhood. Building refers to the common spaces of access and distribution of dwellings, as well as to the building envelope itself. Finally, dwelling refers to the interior space of each home, relative to the different rooms, distribution spaces, and conservation status.

Targeted interventions for each neighbourhood, together with their investment costs, are evaluated through APRAM with these different priority levels, as well as with these social and engagement

indicators, which together facilitate the decision-making process by means of a graphical display of the integral diagnosis.

2.1. Scope of application

The APRAM method specifies the criteria for the sample selection of existing residential neighbourhoods. These criteria are based on architectural and social issues promoted by urban regeneration and active aging policies (Barrios, González, Mariñas, & Molina, 2015; Bibri & Krogstie, 2017). The application parameters include the following:

- Location: European countries. Although this method has already been applied in mainly Mediterranean countries (Spain and Portugal), it could also be applicable to other countries, either within or outside Europe, that must face these urban regeneration and social policies in a similar context. Regarding the demographic scope, it should be applied in residential areas of cities and municipalities of over 20,000 inhabitants.
- Building typology: Residential multi-family buildings that were built during the second half of the 20th century, with an inadequate housing configuration for current social needs, in the form of minimum spaces, low-energy performance in its thermal envelope, and unsuitable security, accessibility and habitability conditions in common spaces and dwellings. This method can also be applied exclusively in energy retrofitting measures, since the social, technical and environmental factors can be assessed in their implementation.
- Conservation status: Slightly deteriorated state of conservation, and normative non-compliance in thermal, security, and/or accessibility requirements.
- Population: Although this method can be adapted to any population sector, given the circumstances of the aging population, it will be suitable to apply this decision-making method in neighbourhoods with a predominantly elderly population, or potentially aged in the coming years. These neighbourhoods are those with more than 30% of residents over 65 years old or with the existence of a population pyramid that indicates a clear trend towards aging residents (European Commission, 2015).

2.2. Technical grid

The assessment method demands an architectural inspection tool whose purpose is to obtain a technical and specialised diagnosis, from an architectural perspective, in each scale of action in order to determine which retrofitting interventions are necessary (AENOR, 2015). The APRAM method therefore defines an inspection tool that enables regulatory compliance, the quality of the spaces, and the conservation status of each case study to be ascertained and assessed.

This tool is defined as a grid template, and is complemented by technical comments, dimensions, and additional information. Regarding the design, each document is organised according to different scopes of analysis, each of which presents information related to the definition of the element, the technical compliance, the conservation status and a final evaluation together with improvement or repair

proposals. Therefore, an inspection sheet is provided for each APRAM application scale, and hence there is a technical grid for the public space, another for the common areas of the building, and a grid for the interior space of the dwelling. Each document is accompanied both by a graphical analysis, through drawings and photographs for the representation of existing damage, as well as the specific evaluation of the envelope in relation to its energy performance, which would enable the analysis of possible energy retrofitting actions. An example of these three inspection grid templates are attached, as supplementary data, and applied in the reference neighbourhood where the method is to be tested. The main content structure of each grid is the following:

- Public space: General and urban data of the neighbourhood, with the same building typology. There is a definition and characterization of the pavement, unevenness, street furniture, lighting, and shade. In addition, there is an assessment of the state of conservation, damage, and major absences in the exterior space design.

- Building: General and administrative data of each selected building. A definition and characterization is given of the building access, portal, vertical communication core, possible elevator, and distribution spaces. In addition, there is a constructive definition of the building envelope and its maintenance status on the façade, roof and floor.

- Dwelling: Basic data is presented that defines the situation, orientation, and distribution of the housing unit. A definition and analysis is given of the design and housing conditions in the living room, bedroom, kitchen and bathroom, and the definition of the existing windows and furniture is also included. Finally, there is a constructive characterization of the dwelling and its conservation status.

The results of this document show regulatory non-compliance, bad conservation status of architectural elements, and/or deficits in basic living conditions due to design shortcomings. The technical team can propose retrofitting interventions, such as architectural demands, for the various problems or breaches diagnosed in each scale. An architectural priority level of action is assigned to the retrofitting interventions proposed, according to the scope and the degree of solution of the problem, which may be normative, design, or maintenance. These three levels of architectural priority are defined below:

- **Low**: The intervention supposes an improvement in the architectural features by means of the inclusion of a new element or the improvement of the design, but it does not solve any normative non-compliance nor does it solve any problem derived from a bad state of conservation.

- **Medium**: The intervention incorporates an improvement in the performance of the space and in the well-being of the resident, and also either resolves the regulatory non-compliance or improves the state of conservation of the architectural element.

- **High**: The intervention introduces a significant improvement in architectural features, and also resolves an important regulatory breach in the conditions of safety, habitability and/or comfort, and improves or renews its state of conservation.

2.3. Residents' Survey

APRAM complements the architectural diagnosis with social and psycho-environmental information through a participatory survey, which enables social perceptions to be obtained to inform the decision-making process in each case study. The survey questionnaire has been designed to be completed in approximately ten minutes, in an anonymous way in order to preserve the privacy of respondents (Ruza et al., 2014). This survey includes 42 questions, related to the public space, building, and dwelling, and is printed on both sides of a single sheet of A4 deposited in residents' mailboxes, or accessed online by means of a web link. Each questionnaire is accompanied by an informative letter that provides residents with information necessary for the questions to be answered and also provides price ranges regarding retrofitting actions.

The survey responses enable the following social and engagement indicators to be analysed:

- Respondent information. Statistical information on the resident filling out the survey (such as age, gender, and period of residence in current dwelling), but also data on household composition (such as family type, number of children and/or elderly people).

- Residential satisfaction is assessed by using three items from Amérigo (1995), that inquire about the degree of satisfaction separately in public space, building, and dwelling. The answer is given in a five-point Likert scale, ranging from "not satisfied at all" to "extremely satisfied". Residential satisfaction index (*RSi*) is obtained [eq. 1], as the relationship between the sum of the satisfaction points of the residents (*s*) and the total number of participants (*P*). This index offers an overall value on resident satisfaction with respect to each of the three scales.

$$RSi = \frac{s}{P} \qquad \text{[eq. 1]}$$

- Place attachment is measured by using three items from the scale developed by Hernández et al. (2007) and refers to the space connection. The answer is also given on a five-point Likert scale, ranging from "nothing" to "very much". The place attachment index (*PAi*) is also obtained [eq. 2] as the relationship between the sum of the attachment points given by the residents (*a*), and the total number of participants (*P*). This index is also applicable to the three APRAM scales.

$$PAi = \frac{a}{P} \qquad \text{[eq. 2]}$$

- Social needs are assessed based on a series of questions, a number of which can be found in Table 1; these are directly focused on the perception that each respondent has in the three scales (public space, building, and dwelling). Each demand or response is quantified and assigned to an intervention. The social needs index (SNi) is obtained [eq. 3] as the relation between the sum of responses demanded by each intervention (y) and the total number of participants (*P*), and then multiplied by the adjustment factor (Ơ=5), since it allows re-scaling in order to range from "no expressed needs" (0) to "high level of needs" (5)

$$SNi = \frac{y}{P} * Ơ \qquad \text{[eq. 3]}$$

- Willingness to participate. Residents also respond to questions regarding participation in carrying out retrofitting interventions and what percentage of the economic investment would be covered in the interventions. Each response is also quantified and assigned to an intervention. The willingness to participate index (WPi) is obtained [eq. 4] as the relationship between the sum of responses for each intervention (y) (adjusting each answer with a reduction factor between 0 and 1 (α) according to the level of economic involvement), and the total number of participants (P). This is then multiplied by the adjustment factor (O=5), since it enables the range to be rescaled from no expressed willingness towards participating in this intervention (0) to a high level of participation (5).

$$WPi = \frac{z * \alpha}{P} * O \quad \text{[eq. 4]}$$

Table 1. Main questions used to create needs and willingness indices.

Questions regarding needs
- Do you consider the following issues to be a problem for the accessible and suitable use of public space? Uneven pavement ☐ | Missing handrails ☐ | Slopes ☐ | Others ☐
- Do you consider necessary to improve or introduce any of the following elements in the garden? Lighting ☐ | Benches ☐ | Fountains ☐ | Handrails ☐ Tables ☐ | Others ☐
- Do you have any mobility difficulties around your building and dwelling? What needs to be done?
- Do you think your building or dwelling needs adjustments or repairs? What needs to be done?
- What do you consider needs to be done to improve the thermal performance of your building/dwelling?
Questions regarding willingness
- Could you afford the costs of repair or improvement? What would your investment budget be?
- Would you be willing to pay specifically for the installation of an elevator? How much?
- Would you be willing to move from your home for the duration of the building work?
- Have you done any building work to improve thermal comfort in your building or dwelling?
- Would you consider reducing the number of rooms to gain space in the rest of the dwelling?
- Would you rent a room that is currently unused in order to obtain more money?

3. Case study

In Portugal, approximately 1,300,000 residential buildings, which account for 40% of the existing housing stock, were built prior to 1970, and hence the building aging index is significant. The government has therefore promoted national renovation policies to adapt residential buildings to the normative requirements and contemporary social needs (National Institute of Statistics from Portugal (INE-PT), 2011; Neto et al., 2014).

This research applies and tests the APRAM in the "Bairro das Estacas", a residential neighbourhood that has been selected as a reference case study of application (Ballarini, Corgnati, & Corrado, 2014). This neighbourhood is located in the district of Alvalade, in Lisbon, and was designed in 1949 by the architects Formosinho and Rui d'Athouguia. This is a reference neighbourhood in Portugal, identified by diverse heritage databases (DOCOMOMO Foundation, 2013; Parracho-Neto, 2015), and recognised with national architectural awards for having been a reference model in the multi-family residential expansion of cities in the twentieth century. Nowadays, this neighbourhood is taken into account and

included in the renovation policies of the city because of its architectural significance and renovation needs.

The "Bairro das Estacas" is composed of four linear residential multi-family blocks, distributed in a parallel and equidistant way. Each block consists of six independent central staircases, resulting in a total of 192 dwellings. Each building has a ground floor and four more storeys. On the ground floor, the concept of residential block is replaced by an uninhabited large green space, simply supported by visible pillars or "estacas".

Figure 2. General view of the case study location.

3.1. Demographic data

Table 2 shows the basic demographic data of the neighbourhood and its historical evolution in the last 20 years in relation to the variables of gender, age, and family unit, based on data from the National Institute of Statistics of Portugal (INE-PT 2011). One third of the residents (33.2%) are over 65 years old, a percentage well above the 23.9% of Lisbon as a whole. According to 2011 data, the age structure of the residents shows a bulk from 51-70 years old (Figure 3), which identifies this neighbourhood with the European demographic trend.

Table 2. Main demographic data from "Bairro das Estacas" (INE-PT, 2011).

Demographic variables / Year		**1991**	**2001**	**2011**
Number of residents	Men	204 *(40.8%)*	173 *(42.8%)*	170 *(41.8%)*
	Women	297 *(59.2%)*	231 *(57.2%)*	237 *(58.2%)*
	Total	501	404	407
Number of residents over 65 years old	Men	33 *(37.1%)*	39 *(37.9%)*	48 *(35.5%)*
	Women	56 *(62.9%)*	64 *(62.1%)*	87 *(64.5%)*
	Total	89 *(17.7%)Total*	103 *(25.5%)Total*	135 *(33.2%)Total*
Number of families	1-2 members	99 *(63.9%)*	104 *(68,9%)*	116 *(75.8%)*

	3 or more members	56 *(36.1%)*	47 *(31.1%)*	37 *(24.2%)*
	Total	155	151	153
Number of families with members:	Over 65 years old	68 *(43.9%)*	74 *(49.0%)*	96 *(62.7%)*
	Under 14 years old	56 *(36.1%)*	60 *(39.7%)*	37 *(24.1%)*
	Unemployed	23 *(14.8%)*	21 *(13.9%)*	16 *(10.4%)*

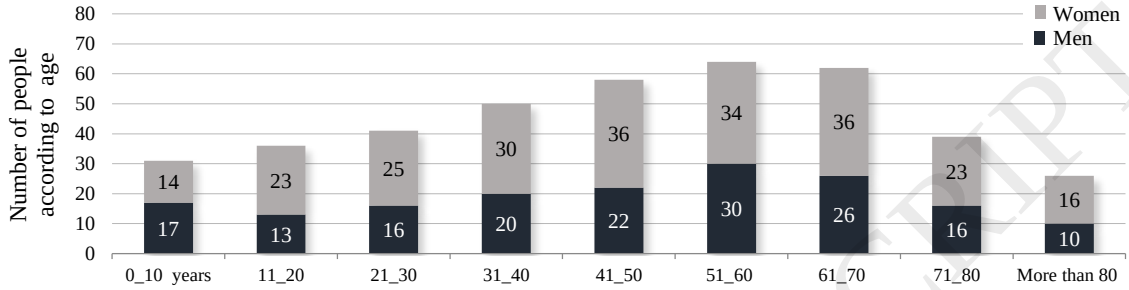

Figure 3. Age structure of the population of "Bairro das Estacas" in 2011 (INE-PT, 2011).

3.2. Recruitment procedure

Technical data was collected through different visits to the neighbourhood from architects and technicians who checked the technical grid in each scale, as can be seen in the supplementary material. Throughout this procedure it was possible to access 17 of the 24 buildings through their independent staircases, thereby rendering the data collection as exhaustive as possible. Regarding the survey recruitment, both a printed version and an online link were provided as alternative ways to complete the survey. The printed version was delivered to each mailbox together with an informative letter and a return envelope for delivery to a specific box in the community centre owned by the local government. In order to inform residents about certain retrofitting actions, information was included with a range of prices so that the approximate economic amount could be taken into consideration. The online questionnaire was created on the "Qualtrics" platform, and a link was provided on the printed version so that it could be filled in online. In order to ensure the maximum response rate, the survey recruitment period was extended to three months.

3.3. Participants

Forty-four responses were obtained (20 online and 24 printed), which corresponds to a response rate of 22.9%. According to a statistical report of the neighbourhood (INE-PT 2011), 12% of dwellings at "Bairro das Estacas" remain unoccupied or are not used as a first residence, and hence the response rate should be taken as being 27.9%. The participant sample is considered representative since there are close resemblances when comparing the participants (Table 3) with the resident population (Table 2). Responses were obtained from all age groups, ranging from residents under 30 years old to those over 80 years old.

Table 3. Characterization of the participating residents.

Variable	Data *(% total)*			
Number of participants		Email 24 *(54.5%)*	Online 20 *(45.5%)*	Total 44 *(22.9%)*
Gender			Men 19 *(43.2%)*	Women 25 *(56.8%)*
Age	0-35 years 6 *(13.6%)*	36-50 years 16 *(36.4%)*	50-65 years 10 *(22.7%)*	More than 65 12 *(27.3%)*
		Minimum 29	Maximum 92	Average 52.6
Period of residence in current dwelling	0-10 years 9 *(20.4%)*	11-20 years 7 *(15.9%)*	21-30 years 5 *(11.4%)*	More than 30 23 *(52.3%)*
Regime			Renters 19 *(43.2%)*	Owners 25 *(56.8%)*
Employment situation		Employed 24 *(54.5%)*	Unemployed 8 *(18.2%)*	Retired 12 *(27.3%)*
Type of household	Non-related 2 *(4.5%)*	Living Alone 13 *(29.5%)*	Couple 23 *(52.4%)*	Couple with child/children 6 *(13.6%)*
Members in each dwelling	1 person 13 *(4.5%)*	2 people 23 *(52.3%)*	3 people 5 *(11.4%)*	4 or more 3 *(6.8%)*
Number of households with members:			Over 65 18 *(40.9%)*	Under 14 6 *(13.6%)*

4. Results and Discussion

4.1. Architectural demands

The architectural diagnosis, by using technical grids specifically applied to the three APRAM scales, enables the identification of which elements are necessary to repair, introduce, or replace through various targeted interventions. The main architectural demands for this case study are as follows:

- **Public space**. Interventions that improve accessibility conditions in gardens and public areas are needed, such as the replacement of broken pavements and the incorporation of adapted and safety routes for people with reduced mobility. It is also necessary to repair certain deteriorated elements, adapt the garden design, and incorporate new urban furniture, especially benches, artificial lighting, and handholds.

- **Building**. There are basic problems with the accessibility conditions. It is necessary to incorporate an elevator, correct the unevenness of the portal access, incorporate handrails, and increase the useful width in the door access of dwellings. Regarding the status of conservation, repair operations are necessary on the façade and on the roof to eliminate fissures, cracks, and damp. The incorporation of insulating materials on the façade and on the roof are also required in order to improve the thermal performance.

- **Dwelling**. Distribution problems exist, with minimum space in each room. It would therefore be possible to reduce the number of bedrooms to obtain larger spaces. Actions are especially needed for the improvement of the useful space and distribution in the bathroom and the kitchen. It is necessary to replace windows with those of better thermal performance in order to improve interior comfort and energy consumption.

Each proposed intervention is valued from an objective architectural perspective, through a priority level assignment, according to the degree of compliance introduced by each measure, as explained in Section 2.2. The proposed list of interventions and their assigned level of priority is detailed in Section 4.4, where an integral diagnosis is displayed to facilitate decision-making in this case study renovation.

4.2. Residents' perceptions

The answers in the survey offer psycho-environmental impressions from the residents, their fundamental needs, and their motivation to act sustainably and effectively in their housing environments. Satisfaction and attachment levels that residents experience in each scale are extracted in order to give an overall view of the residents' perceptions regarding their public space, building, and dwelling.

- **Residential satisfaction** levels are medium-high rates according to public space (RSi=4.26), building (RSi=3.86), and dwelling (RSi=3.79), and hence the overall satisfaction index, on a five-point scale, is close to four (M_{RSi}=3.97, SD=0.83). However, there are major variations according to the age of respondents, since residents under 40 years old have a higher average satisfaction index (M_{RSi}=4.3, SD=1.0), while for respondents over 59 years old, this overall index is lower (M_{RSi}=3.1, SD=1.1).

- **Place attachment** levels are also acceptable regarding public space (PAi=4.04), building (PAi=3.79), and dwelling (PAi=3.87). The average attachment index is also close to four (M_{PAi}=3.90; SD=0.82), in fact, 80% of residents feel attached or very attached to the public space, however, in buildings and dwellings, the rates are lower. Residential satisfaction and attachment take different paths within the different residents' groups. Attachment is marginally and positively correlated with age whereby elderly residents feel more attached than satisfied.

Once the architectural inspection was carried out and architectural demands delved into a retrofitting intervention list, the survey answers allow each intervention measure to be assigned an entry in the need and willingness indices.

- **Social needs** are important in this case study: more than 80% of respondents' demand at least one improvement or adaptation. Regarding public space, the most commonly demanded needs are related to the adaption of the accessibility conditions of the garden, with special emphasis on the need to repair broken pavement (SNi=4.32), install railings and handrails (SNi=4.12), and to regularize the existing architectural barriers (SNi=3.67), as well as the need to incorporate and improve the distribution of benches (SNi=3.78) and to improve the artificial lighting (SNi=3.52). Regarding buildings and dwellings, 83% and 86% of respondents, respectively, stated that their building or dwelling needed at least one intervention. The most highly demanded interventions are related to daily basic actions, such as improvements to the accessibility conditions of the building (SNi=3.86), handrail instalment (SNi=4.23), incorporation of elevators (SNi=4.14), and adaption of the distributions of the bathroom (SN=4.18) and kitchen (SNi=4.18). Other highly demanded actions are linked to the improvement of the exterior appearance of buildings, by repairing or painting exterior façades (SNi=3.53). Finally, it

should be borne in mind that most of the population reported feeling cold or hot in their dwellings and would like to implement energy-efficient actions, such as insulating the façades and roof (SNi=3.77), replacing windows (SNi=3.60), and installing outdoor awnings (SNi=3.09).

- The **willingness to participate** index has also been established for each intervention to assess the intervention feasibility (Serrano-Jimenez et al., 2017; Vilches et al., 2017). These WPi levels have generally been lower than those of the SNi. Moreover, 76% of respondents could participate and pay the costs entirely or partially, while there were families with major needs who could not participate due to economic restrictions. Special attention should be paid to the financing of an elevator index (WPi=3.17), as one of the most highly needed and expensive operations. In fact, the WPi increases in people over 60 years old, which demonstrates a greater economic effort in the elderly within situations of high levels of need. A positive correlation between SNi and WPi was found, which means that those interventions with higher levels of needs are also the ones more willing to participate in the solution.

The APRAM method permits a specific social analysis to be obtained according to variables of gender, age, or time of residence. This specific diagnosis enables retrofitting interventions to be adjusted to specific population groups in order to achieve greater success. Figure 4 shows the overall averages of the residents' perceptions depending on their age, corresponding to all residents and also specifically the young (up to 40 years old) and elderly (over 60 years old) populations, which present variations and specific particularities in these four indices. According to this figure, the elderly residents (over 60 years old) feel that they have greater needs than average resident and are less willing to participate in certain retrofitting interventions, due mainly to their economic limitations for these actions to carried out. However, lack of knowledge regarding their benefits and their apathy towards addressing non-urgent problems in their residential environment also constitute influential factors.

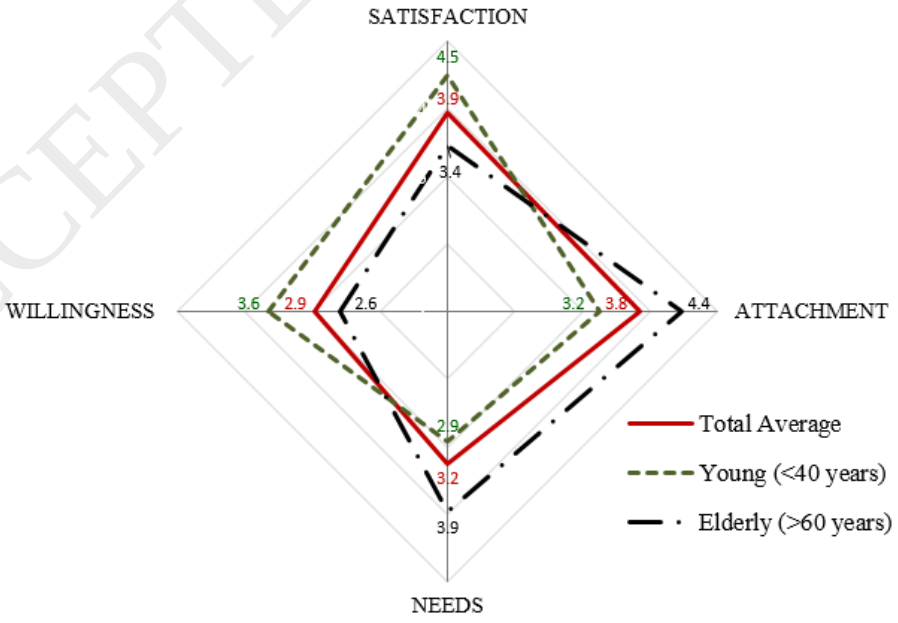

Figure 4. Social and engagement indicators according to the age of participants.

4.3. Integral diagnosis of retrofitting interventions

Table 4 shows all the APRAM results for this case study. This table presents a list of interventions, classified according to three scales, with their corresponding intervention costs obtained from real construction companies and private entities. These retrofitting actions have been proposed from an architectural diagnosis developed by the technical team, through the use of technical grids. Regarding the architectural diagnosis, each intervention is objectively assessed with a priority level according to the solution that it incorporates, while in relation to the social diagnosis, each of these three scales is contextualized with a satisfaction and attachment level and each measure is assessed subjectively with a level of social needs and willingness to participate, based on the survey responses. A multidisciplinary analysis is presented, where the architectural priority and the needs and willingness indices are combined. The results of this method facilitate decision-making for owners, neighbourhood communities, urban agents, and public entities regarding the choice between various viable and effective interventions based on their different results.

Table 4. Summary table of the APRAM integral diagnosis.

PUBLIC SPACE	**Residential satisfaction**		**Place attachment**		
	4.26		4.04		
	Intervention	**Architectural Priority**	**Social needs**	**Willingness to participate**	**Cost[1]**
	A.1 Place railings and handrails in routes and building access	High	4.12	3.84	3,424.00 €
	A.2 Place new benches and improve their disposition	Medium	3.78	2.74	4,330.00 €
	A.3 Install water sources	Low	3.04	2.36	1,742.00 €
	A.4 Improve lighting and introduce automatic devices	High	3.52	3.56	7,520.00 €
	A.5 Repair broken pieces and slopes on the pavement	High	4.32	4.48	4,180.50 €
	A.6 Eliminate existing architectural barriers and unevenness	High	3.67	4.08	5,752.00 €
	A.7 Introduce artificial lighting on the pavement	Medium	2.54	1.82	2,652.00 €
	A.8 Incorporate physical exercise facilities	Low	3.65	3.25	4,425.00 €
	A.9 Improve the drainage of water in public space	Medium	2.26	2.93	6,560.60 €
	A.10 Adapt access to commercial premises of the public space	Low	2.04	2.48	2,950.80 €
BUILDING	**Residential satisfaction**		**Place attachment**		
	3.86		3.79		
	Intervention	**Architectural Priority**	**Social Needs**	**Willingness to participate**	**Cost[1]**
	B.1 Improve portal accessibility with a ramp	High	3.86	4.05	3,855.00 €
	B.2 Implement a wider portal door	Medium	2.86	2.41	1,450.00 €
	B.3 Place adapted handrails and supports	Medium	4.23	3.95	1,654.80 €
	B.4 Install stair-lift platform in portal (3-5 steps)	Medium	1.83	1.25	4,950.00 €
	B.5 Install elevator (outside the building - 3 storeys)	High	4.14	3.17	42,000.00 €
	B.6 Install automatic lighting with presence detectors	Low	1.83	1.42	1,050.00 €
	B.7 Install storage on portal with mailboxes and mechanisms	Low	3.46	2.64	1,825.00 €
	B.8 Replace non-slip flooring in common spaces	Low	2.89	2.23	2,958.00 €
	B.9 Repair exterior cracks, fissures, and damp on façades	High	3.53	3.95	6,850.00 €
	B.10 Incorporate insulating materials in façades and roofs	High	3.77	3.57	4,775.00 €
DWELLING	**Residential satisfaction**		**Place attachment**		
	3.79		3.87		
	Intervention	**Architectural Priority**	**Social Needs**	**Willingness to participate**	**Cost[1]**
	C.1 Implement wider doors	Medium	3.35	2.43	736.00 €
	C.2 Adapt handrails in corridors and distribution spaces	Low	2.92	2.78	387.50 €
	C.3 Repair interior cracks, fissures and damp	Medium	3.41	3.69	1,862.00 €
	C.4 Place rolling awnings and blinds	Low	3.09	2.74	2,045.00 €
	C.5 Replace windows for better thermal performance	Medium	3.60	3.14	3,758.00 €
	C.6 Install specific rails and handles in bathroom	Low	3.83	4.08	172.50 €
	C.7 Replace bathtub with shower	High	3.98	4.28	784.00 €
	C.8 Spatially adapt the bathroom distribution	High	4.35	4.11	2,596.00 €

C.9	Spatially adapt the kitchen distribution	High	4.18	3.87	2,850.00	€
C.10	Redistribute the dwelling	Medium	3.57	3.49	3,960.00	€

1. Investment cost per public space, building or dwelling. All costs incurred up to the point when the service or the building element is delivered to the residents, ready to use. These costs include design, purchase of building elements, installation, and commissioning processes, excluding national taxes.

Residents from "Bairro das Estacas" have shown medium-high satisfaction and attachment levels. However, 80% of responses, mostly from people over 60 years old, consider that public space, buildings, and dwellings fail to meet their basic requirements or needs. It has been revealed that more than 80% of residents consider that at least one improvement or intervention is needed in their residential environment. There is also close agreement between the architectural diagnosis and residents' perceptions. Certain major retrofitting interventions, such as the improvement of the suitability of access to the building, the installation of an elevator, and the public space improvement, are demanded from both an architectural and a social point of view. However, there are views regarding diverse retrofitting interventions that differ between those responsible for the architecture and what residents demand and would be willing to do.

The graphic output in this method can be broad and varied, since they depend on which factors are highlighted in order to facilitate the decision-making process. Figure 5 represents retrofitting interventions, in the public space, building, and dwelling scales, with different symbology to indicate the architectural priority levels, and these interventions are located on the x and y axes in accordance with the levels of social needs and willingness to participate, respectively. These figures allow the performance of each intervention to be graphically analysed depending on the architectural criteria and the occupant behaviour.

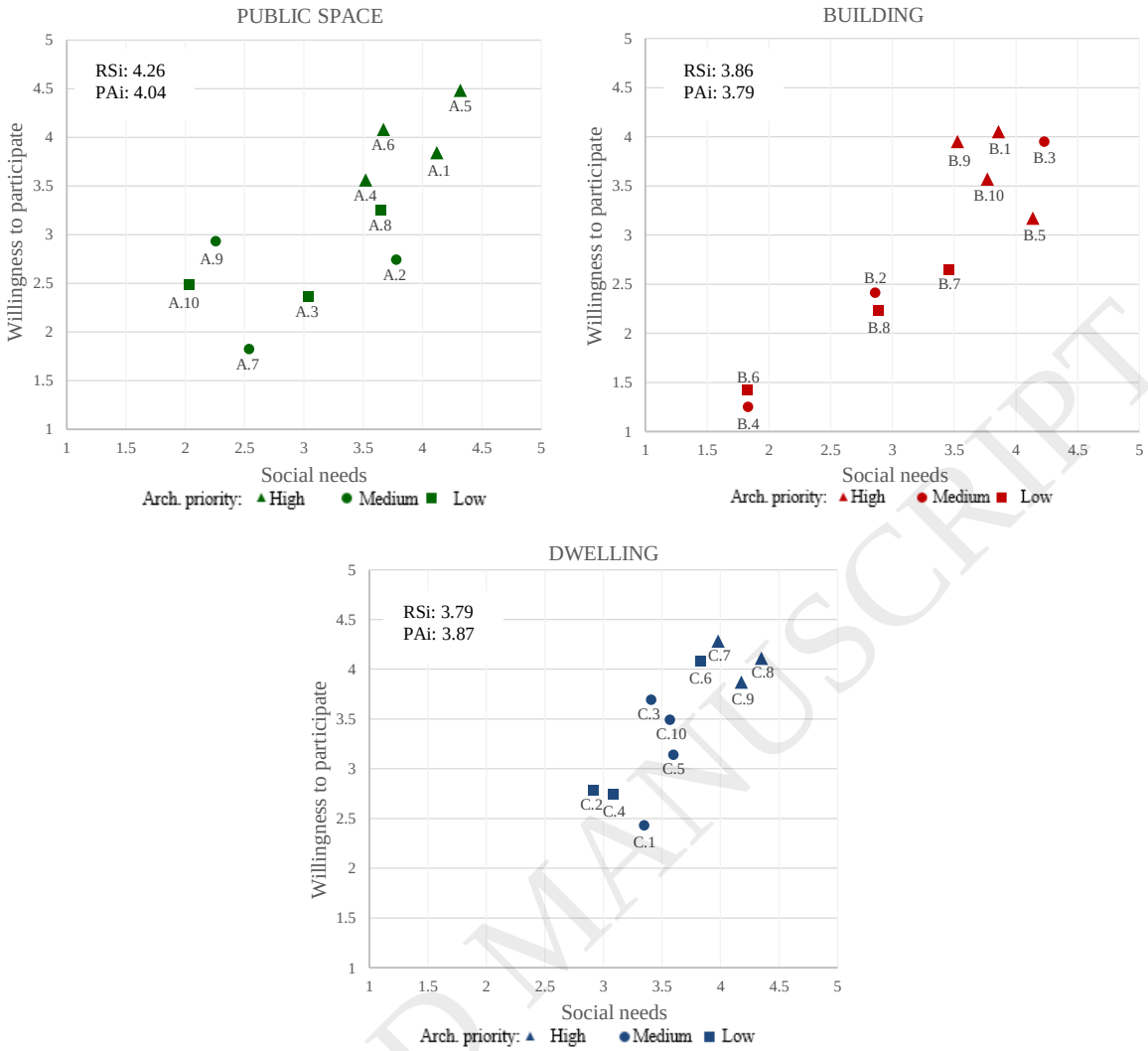

Figure 5. APRAM assessment for various retrofitting interventions according to each application scale.

These graphics demonstrate the affinity between the architectural priority levels and the psycho-environmental indices, with a significant relationship between the social and architectural criteria, except for certain measures. The effectiveness of this method lies in diagnosing which measures are the best valued from both disciplines (A.5, A.6, A.1; B.1, B.3, B.9; C.8, C.7, C.9), while also taking into account the cost of their intervention.

Figure 6 represents a new analysis that combines the social needs index with their intervention cost. This figure also presents a different symbology to indicate the priority levels and different colours according to each scale where they are applied. This enables the identification of which measures meet high needs with low (up to 2,000€) or medium prices (between 2,000€ and 4,000€).

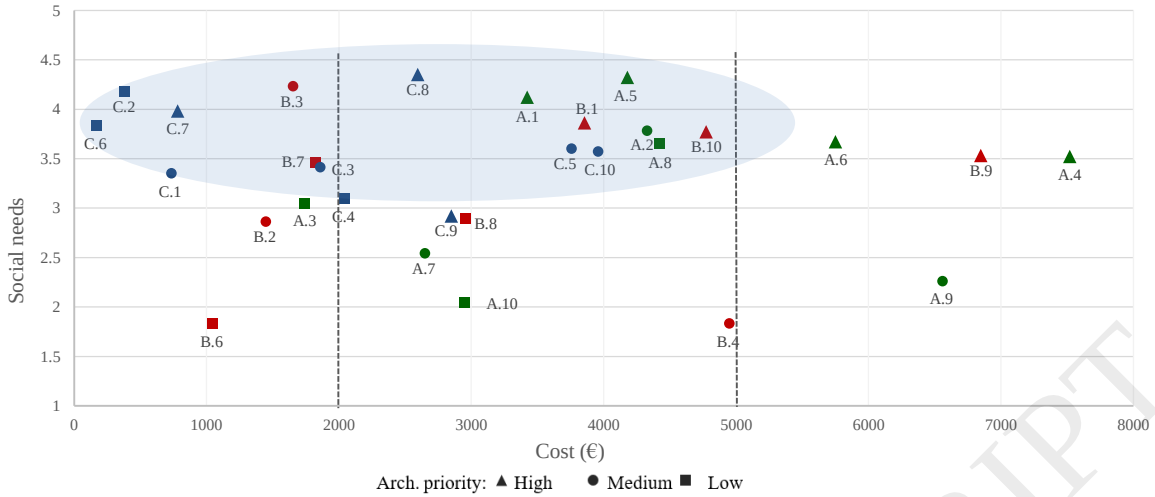

Figure 6. Intervention assessment according to social needs and economic investment.

The shaded area marks those interventions that have a high rate of social benefit according to their residents, as well as an affordable intervention cost, either below 2,000€ or between 2,000€ and 4,000€. The symbols also help identify those measures with a higher architectural priority. According to the results, it is observed how the architectural priorities do not exactly align with the level of social needs, which shows that although there is a major agreement between the two disciplines, it is necessary to address the variations between the technical and social demands for an efficient urban regeneration that satisfies the specific demands of residents even if they are not an architectural priority. The identification of these types of measures is one of the reasons why this interdisciplinary method is defined, since it enables decision making to be simultaneously effective in the architectural, social, and economic fields.

5. Conclusions

This research introduces a new interdisciplinary method, specifically designed to be applied in building renovation, which is useful as a decision support system to achieve urban regeneration and aging population targets. This Architectural and Psycho-environmental Retrofitting Assessment Method (APRAM) combines architectural, from a technical inspection grid, and psycho-environmental results, through a participatory questionnaire, in three application scales: public space, building, and dwelling. This method enables an integral diagnosis to be attained for both neighbourhood and residents, which supports the decision-making process of retrofitting interventions whose objective is to improve the well-being and quality of life of people, especially the elderly, who reside in neighbourhoods of a high degree of obsolescence.

The APRAM method is defined as an open and flexible method which adapts to real applications through a broad scope of application, within different contexts and requirements, and can be extrapolated to various case studies with different socio-economic conditions. In fact, the results obtained may be extrapolated to those neighbourhoods with similar application parameters, although at all times it is

recommended that the technical grid be employed as well as the participation survey in order to address the proposals in a more specific way.

The originality of the research lies in the contribution of the design of a decision-making system, and its corresponding application in a real case study, which considers a more effective collaboration between disciplines in the residential renovation process, thereby demonstrating that, through an effective work method, an effective and more sustainable renovation can be obtained that integrates various actors from its early stage up to the decision-making phase. In addition, the method incorporates a specific inspection tool for urban and building renovation, and a participatory survey that can be applied in any multi-family residential neighbourhood where the renovation process is carried out. The utility of this method is to serve owners, resident communities, private developers and public entities in their decisions regarding which interventions are the most optimal from technical and social points of view.

In this research, APRAM has been applied and tested on a real case study from Portugal. The results obtained for this case study, structured into three scales, have integrated architectural demands and residents' perceptions, through multiple factors of analysis that provide a decision support system. The effectiveness of APRAM lies in the presentation of a summary table with the integral diagnosis of retrofitting interventions, as well as a data output graph that enables costs, architectural priorities, social benefits, and participation involvement of residents to be analysed. Through this method, any analysis can be tailor-made to include specific population sectors, such as the age of the residents, period of residence, and gender, which enables specific population groups to be targeted for inclusion in the decision making. The design of this method can also be applicable to energy renovation strategies exclusively, whereby the comfort introduced and the influence of occupant behaviour can be evaluated via both disciplines in the decision-making of energy retrofit actions.

This research therefore establishes the need to involve residents in these architectural studies by working with an interdisciplinary method that combines architecture and environmental psychology to successfully promote urban regeneration and aging in place. It is necessary to consider the financial vulnerability of owners in any building renovation by means of proposing interdisciplinary studies for the development of sustainable and effective strategies. This study is also proposed as the basis for future research, in that the procedure and data obtained herein can be applied to support the decision-making of architectural proposals. Finally, this research may exert an impact on several other lines of research involved in the evaluation of retrofitting interventions through sensitivity analysis from various perspectives.

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